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published in
Journal of Biomechanics
2001

DOI (link to publisher)
10.1016/S0021-9290(00)00210-4

ELSEVIER

Journal of Biomechanics 34 (2001) 405–408

JOURNAL OF BIOMECHANICS

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Technical note

The effect of passive vertebral rotation on pressure in the nucleus pulposus

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Accepted 3 July 2000

Abstract

To study the immediate effects of axial rotation on the intervertebral disc, six pig cadaver lumbar functional spinal units were exposed to rotations of up to 2°, while disc height and intradiscal pressure were measured. The results showed that rotary movements are capable of causing an immediate increase in disc height and drop in nucleus pressure. However, the long-term effects were opposite in direction.

Keywords: Annulus fibrosis; Biomechanics; Intervertebral disc; Intradiscal pressure; Spine

1. Introduction

Small intervertebral movements, for instance during walking, appear to reduce low-back pain (van Deursen and Patijn, 1993) and have been hypothesized to prevent degenerative changes of the intervertebral disc (Evans et al., 1989). These intervertebral movements include flexion, lateral bending, and torsion. Recent findings have supported the importance of small rotary stimuli by showing effects on body height changes and thus, on time-related disc height changes (van Deursen et al., 2000).

The question therefore arises, by what mechanism might small axial intervertebral rotation contribute to short-term pain relief and long-term prevention of degeneration and low-back pain. Mechanical and structural considerations led us to believe that torsion might have an immediate (mechanically induced) effect on disc height and intradiscal pressure. In turn, these changes might affect the pattern of fluid loss and depressurization of the intervertebral disc which occur in daily loading. We therefore hypothesized that, small torsional deformations of the disc have a direct mechanical effect on disc height and nucleus pressure.

2. Methods

Six pig cadaver lumbar functional spinal units (two vertebral bodies and an intact disc) were clamped in a specially designed apparatus. Facet joints and spinal processes were removed to facilitate fixation of the specimens. The lower vertebral body was exposed to small, stepwise applied (target position achieved in less

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0021-9290/01/$ - see front matter
PII: S0021-9290(00)00210-4

than 0.1 s), alternating rotations (three repetitions of 30 s left, 30 s zero, 30 s right, 30 s zero torsion). Four blocks of 0.5°, 1.0°, 1.5° and 2.0° were applied. The order of the rotations was systematically varied between specimens. The upper clamped vertebral body was attached to a horizontal XY-gliding plate, to realize axial rotation around a non-imposed axis and without bending. In addition, the upper vertebral body was continuously compressed with 340 N and could move freely in vertical direction. The protocol is illustrated in Fig. 1. Disc height change was measured with an inductive sensor, attached to the uppermost clamp. Intradiscal pressure was measured with a miniature pressure transducer build into a 0.9 mm needle (Gealtec Ltd, UK). All data were continuously sampled at 100 Hz and digitally low-pass filtered (Second-order Butterworth, cut-off frequency 10 Hz). A Kelvin unit function was fitted through the data obtained before the alternating torsional increments were imposed. Disc height and pressure changes were statistically analyzed using repeated measures ANOVA and post hoc paired *t*-test for difference between subsequent rotation steps.

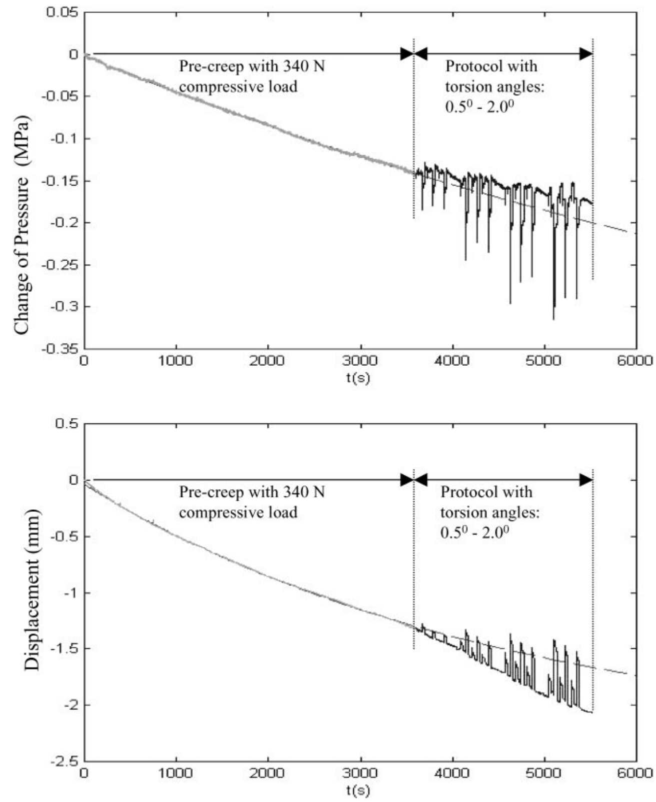

Fig. 1. Illustration of the measurement protocol. The top window illustrates the drop (2.2–6.7%) in pressure (from a mean baseline level of 0.45 MPa), the bottom window illustrates the change in specimen height. Note that, in this case, the rotations were applied in increasing order. The order was systematically varied between specimens. The dashed line represents the fit on the data obtained before applying rotation.

3. Results

The imposed torsion of the lower vertebra appeared to cause immediate increase in disc height, ($F_{3,15} = 34.98$, $p < 0.001$ accompanied by a decrease in intradiscal pressure ($F_{3,15} = 9.96$, $p < 0.007$). Post hoc differences between most adjacent levels of torsion were found to be significant (Fig. 2). In contrast, compared to the extrapolated creep curve, alternating torsion appeared to enhance disc height loss and to delay nucleus pressure loss in all specimens (Fig. 1).

4. Discussion

We found that axial rotations of less than 2° had consistent instantaneous effects on the disc. Disc height increased and intradiscal pressure decreased. These effects of pure-axial rotation have, to our knowledge, not been studied before.

It should be noted that the zygapophysial joints were removed from the specimens. Although this may have affected the results, we expect this to be limited, since the range of rotations studied is considered to be within the free interspace of the zygapophysial joints (White and Panjabi, 1978).

The instantaneous effects found in this study could be explained by a reduced compressional compliance of the annulus as a consequence of the torsional deformation. The consequent non-linear strain of the annulus fibers and compression of the matrix could lead to an increased apparent Young's modulus. The depressurization and height gain might allow the disc to delay fluid loss or even reabsorb fluid and regain height over time. This would have an immediate, pain-reducing effect by decreasing contact forces on facet joints, increasing the foraminal space (Dunlop et al., 1984), and normalizing pressure distribution in the disc (Adams et al., 1996). In addition, it can be assumed that it enhances avascular nutrition and thus counteracts degenerative changes (McMillan et al., 1996).

Although the study was not specifically designed to assess these potentially beneficial long-term effects, this point merits some discussion. Indeed, a decelerated pressure loss was found to occur in the current study. However, this was accompanied by an accelerated instead of decelerated height loss over time (Fig. 1). These long-term effects might be explained by rotation enhanced fluid loss from the annulus both to the environment and to the nucleus. This would result in an increased loss of height as shown, and can be expected to increase the intradiscal pressure, also in line with our findings. If this were to be the case, the positive effects with respect to facet joints and foraminal space

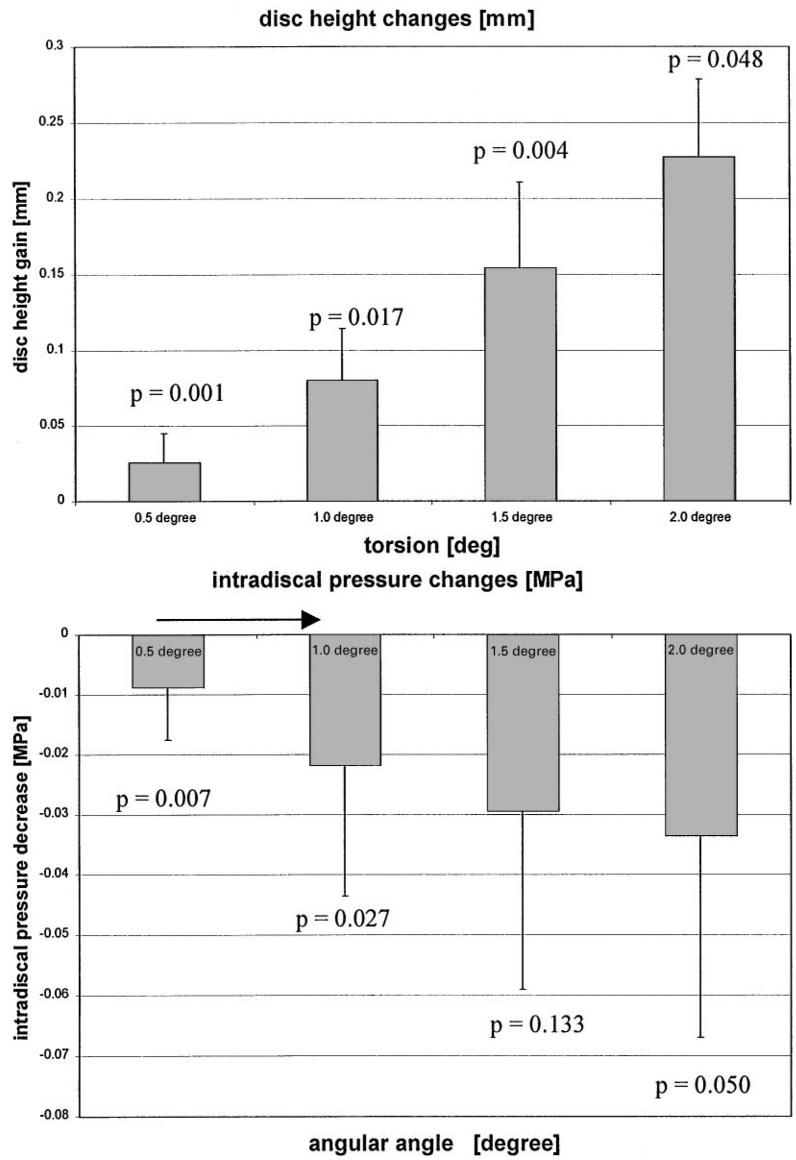

Fig. 2. Upper Mean disc height gain (mm) versus torsion angle of vertebral body [degrees]; lower Mean intradiscal pressure decrease (Mpa) versus torsion angle. *P*-values for significance are given compared to the previous rotation angle (post hoc 2-tailed paired *t*-tests). Mean values and standard errors (see bars) were calculated from the six specimens.

would be obviated and the net result would be adverse. However, data obtained in vivo indicate that the long-term effect of cyclic rotation is an increase in disc height (van Deursen et al., 2000), We therefore believe that, performance of the experiment in absence of a fluid environment and frozen storage (Bass et al., 1997) may have contributed to this finding. An alternative explanation for the accelerated height loss and decelerated drop in pressure could be hysteresis of the annulus fibers. This would also enhance height loss and it would cause a shift of weight bearing from the annulus to the nucleus. However, in this case, the nucleus would also be less confined by the annulus, which would affect the nucleus pressure in the opposite direction. In addition, such a mechanism is not compatible with height gain due to rotation in vivo.

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